Instruments

THE MAGAZINE OF

Measurement and Control

Vol. 12
OCT.
1939
No. 10

Providing Precise Temperature Records . . . Handsomely!

A Complete Line of Modern TAG Recorders with 3 Chart Sizes

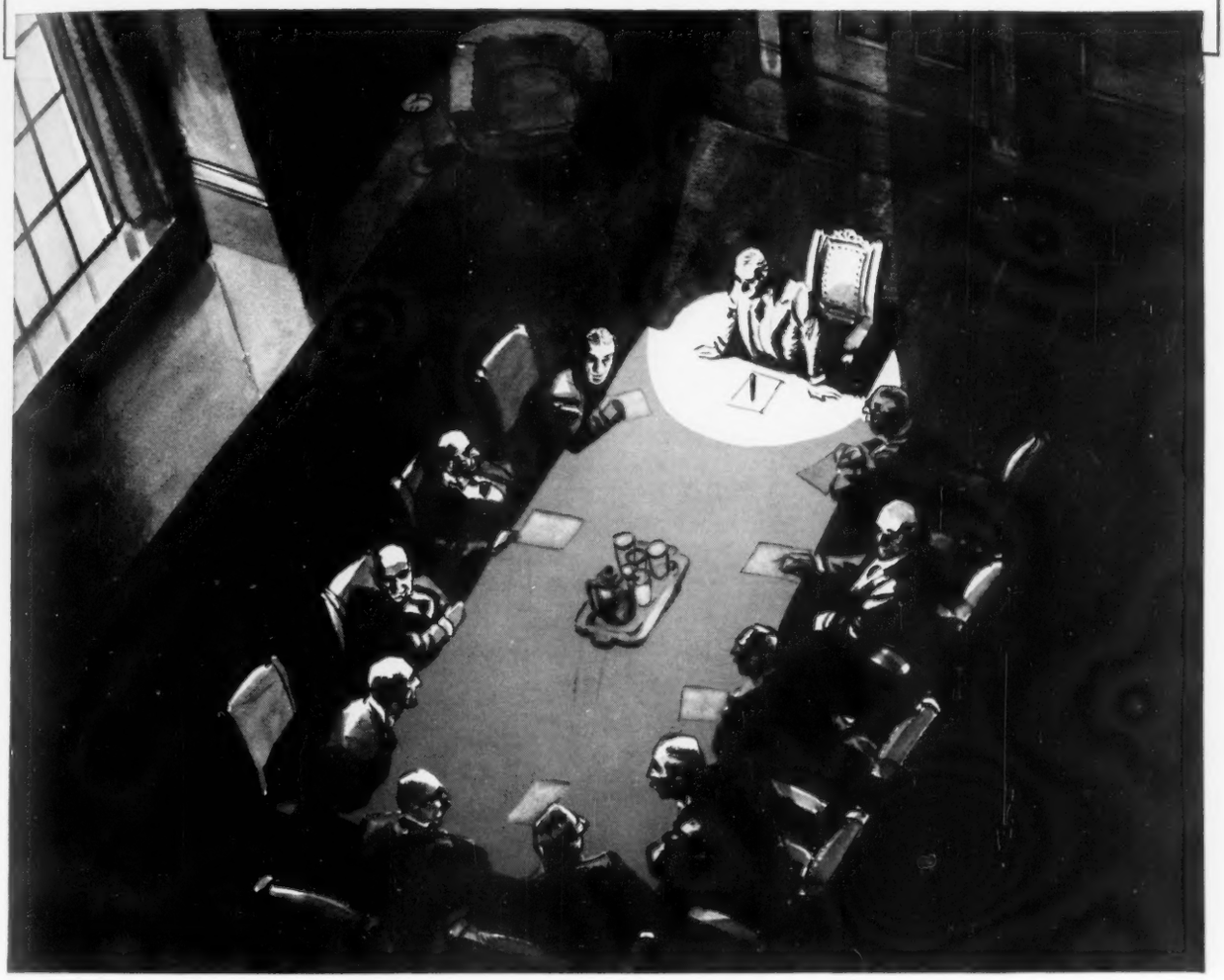
"Handsome is as handsome does" is an apt description of TAG's complete line of new day Recorders . . . For, in these handsomely styled Instruments, modern design finds quick agreement with the approved standards of sensitive reaction, characteristic of TAG Temperature and Pressure Recorders.

Offered in 9", 10" and 12" chart sizes, all TAG Recorders have an exceptionally long pen travel and an interchangeable tube system of ingenious design . . . the active element can be replaced readily and needs be checked at one temperature only—no necessity to recalibrate all points in the range. Ask for your copy of Catalog 1060-I which will suggest the usefulness of TAG Recorders for service and economy in your plant.

C. J. TAGLIABUE MFG. CO.

Park & Nostrand Ave's., Brooklyn, N. Y.

"Who is this man that can cut our operating costs?"



"TAXES are up . . . so are wages and material costs," said the Treasurer. "If we're to make a profit this year, we've got to cut operating costs. Frankly, I don't see how . . ."

The production executive spoke up. "I know where you can get a man who'll show you how. And it won't cost a cent."

"Who is this man?" the Treasurer asked. "Let's get him in . . ."

Two days later the man arrived . . . made a free survey of the plant. As a result of the survey, automatic controls were installed throughout.

Six months elapsed. Then one day the production executive was stopped in the hall by the Treasurer.

"Thanks to your suggestion, we're in the black," said the latter. "Those Taylor Automatic Controls have already paid for themselves—and now we're operating at a nice profit."

* * *

THIS STORY is typical of the way Taylor is helping industry to overcome the problems of today—the problems of higher taxes, of increased material and labor costs.

For Taylor shows you how to attack the one cost which you can reduce—operating cost.

Taylor Automatic Controls can insure the uniformity of your product . . . can reduce spoilage and speed production. This means more sales and greater profits for you.

Write today for a Taylor man to make a free survey of your plant. No obligation of course. Taylor Instrument Companies, Rochester, N. Y. Plant also in Toronto, Canada. Manufacturers in Great Britain: Short & Mason, Ltd., London, England.

Taylor

Indicating / Recording • Controlling

TEMPERATURE, PRESSURE, FLOW *and* **LEVEL INSTRUMENTS**

Test your CONDENSERS at work with the AEROVOX L-C CHECKER

Completely self-contained. Operates on 105-130-v. AC or DC. Covers frequency range of 60 kc. to 26 mc. 4¾ lbs. 10½ x 7½ x 5½ in. Steel case with black wrinkle finish.

●

Checks capacity of condensers at radio frequencies without removing from circuit.

●

Tests combinations of inductance and capacitance. Adjusts circuits to top efficiency.

●

Simplifies alignment of r.f. circuits. Aids in tracking super-het. oscillators, and tuning wave traps.

●

Checks frequency ranges of receivers and wavemeter calibrations.

●

Checks identifying harmonics of frequency standards.

●

Checks natural resonant points of r.f. chokes, making sure they are beyond operating range.

●

Traces resonant absorption trouble in "all-wave" receiver circuits. Locates resonant points in shorted windings.

●

Checks natural period of antennae and transmission lines.

●

Etc., Etc. Yet costs only $29.50 net, including tubes.

●

● This inexpensive instrument tests condensers and inductances in the radio-frequency range under conditions simulating *actual operating conditions!* Determines effectiveness of capacity or inductance *while actually connected in its circuit.* It's a true radio check the *radio* way!

You won't believe such things can be done until you've seen the L-C Checker in action. Here's a unique, simple, indispensable instrument for anyone working with radio-frequency components and circuits. Don't fail to see it!

Write for Data . . .

Descriptive folder is yours for the asking. Write us direct or, preferably, ask your local AEROVOX jobber to show you the L-C Checker. Try it for yourself.

AEROVOX CORPORATION
NEW BEDFORD, MASS.
IN CANADA: AEROVOX CANADA, Limited Hamilton, Ont.

Instruments
THE MAGAZINE OF MEASUREMENT and CONTROL

Vol. 12 No. 10

OCTOBER 1939

FRONT COVER: Fever therapy machine, Pittsburgh City Hospital, Mayview, Pa. One of nine used in fever therapy research conducted by University of Pittsburgh with $50,000 grant from Westinghouse Electric & Manufacturing Co.

Courtesy Westinghouse Electric & Manufacturing Co.

EDITORIAL COMMENT 265

AUTOMATIC CO_2 COMPENSATOR FOR CUPOLA CONTROL 275
By F. K. Vial
This paper received the first prize of $200.00 in the First Annual Instrumentation Contest

AN AUDIO-FREQUENCY SPECTROMETER 277
By R. K. Hellman
This paper received the second prize of $100.00 in the First Annual Instrumentation Contest

A HYDROGEN SULPHIDE RECORDER 280
By Wilton E. Stackhouse
This paper received the third prize of $50.00 in the First Annual Instrumentation Contest

NEW INSTRUMENTS 266
Indicators, recorders, controllers, inspection devices, etc., for plant, field and laboratory

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THE MAGAZINE OF
Instruments
Measurement and Control

M. F. Béhar, Editor

Publisher's Note: With this issue the editorial pages are turned back to Major Béhar, who has recovered sufficiently to leave the hospital and be at home. It will be some time though before he will be able to be at his desk.

For The Good of The Nation

WITH INDUSTRY setting a record pace, there will naturally be more interest in measurement, inspection, testing and control. Therefore, the present will be an opportune time to point out the advantages resulting from the installation of such devices.

So much publicity has been spread about campaigns of modernization and efficiency or the installation of instruments and controls replacing man-power that data on the other side of this question should be given.

The individuals, who have no contact with industry, probably think that our country is now mechanized to its fullest possibilities. Intriguing and labor-saving devices are featured in magazine articles because they are the unusual, not the usual. Every plant in the country is permeated with obsolete methods of production.

The announcement of The Second Annual Instrumentation Contest offers an exceptional opportunity to call attention to the services performed by instruments and controls.

We urge you again to read the Contest Entry Blank (a copy is enclosed with this issue) and submit your contribution before November 15th. In the meantime return the business reply card advising that you plan to send in an entry. The prize winning papers will appear in the January issue of INSTRUMENTS.

The readers of **Instruments** know that the good of the nation, in the last analysis, depends largely upon (1) "saving money" and (2) "making jobs." It is hoped that you—many hundreds of you—will enter the contest and describe case studies from your experience.

It is not amiss to sum up some of the ways in which **instruments save money.** These are as follows: Fuel saving, materials saving, prolonging the service-life of processing equipment, increased production from processing equipment, better quality of product, uniformity of product, minimization (sometimes total elimination) of rejects, accident prevention, and minimizing reliance on human watchfulness. As for the advantage usually called "labor-saving," think of it—and write about it—in terms of minimizing the sum total of human drudgery.

It is in order, likewise, to mention some ways in which **Instrumentation makes jobs.** These are as follows: By making possible the creation of new industries which would not even have been launched without it. (Examples, petroleum refining, rayon, rubber, etc.) By expanding industries whose growth depends upon the existence of instrument-created industries. (Example, the modern automobile industry which depends on instrument-made knockless gasolines, instrument-made tires, instrument-made alloys, etc.) By expanding industries whose growth depends upon ability to reduce prices of products in order to win the mass markets. By creating new industries which largely supplant competitive imports. By creating new industries which absorb the surplus products of our fields and forests and create demands for new crops. By creating new industries which tend to relieve our dependence on strategic and critical materials.

SYMPOSIUM ON TEMPERATURE, ITS MEASUREMENT AND CONTROL IN SCIENCE AND INDUSTRY

This symposium will be held in New York City at the Pennsylvania Hotel, November 2 to 4, 1939, by the American Institute of Physics, 175 Fifth Avenue, New York, with the cooperation of the National Bureau of Standards, the National Research Council, and officers and committees of scientific and technical societies.

The program is in charge of representative committees of authorities in various fields, who have arranged for a program of 100 or more papers on scientific and technical subjects, which will be presented in concurrent sessions of selected groups. All interested persons active in science or engineering are cordially invited to attend the sessions, and take part in the discussions of papers. A complete program containing full abstracts of the papers to be presented will be mailed in advance on request to the Institute. It is suggested that those who expect to attend will inform the Institute and make their hotel reservations early. There will be a registration fee of $1.00. The Chairmen of the committees are Gustav Egloff, A. W. Ewell, C. O. Fairchild, J. D. Hardy, H. F. Mullikin, F. H. Norton, R. B. Sosman, C. B. Veal, H. T. Wensel, and C. B. Wilkes. H. A. Barton, Director of the Institute, is Chairman of the Main Committee.

BAILEY METER CONTROL SYSTEM

The Mark of

Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

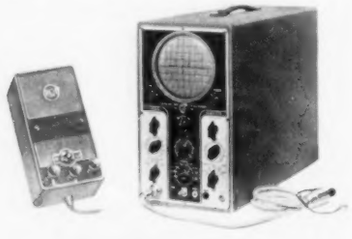
BAILEY METER COMPANY

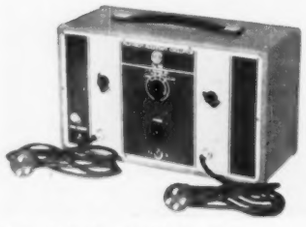
1041 Ivanhoe Rd., Cleveland, Ohio

The MONTH'S NEW INSTRUMENTS

Test Instruments For Television Servicing

Three new pieces of television test equipment, a piezo-electric calibrator, a 5-inch wide-range oscillograph, and a television alignment oscillator, have been carefully designed in accordance with present-day television receiver development, and in addition include provision for future television progress, thus minimizing the possibility of obsolescence. The alignment oscillator is a newly developed instrument specifically designed for visual alignment of the r-f and i-f circuits in television receivers. The calibrator and the oscillograph, while indispensable for television servicing, have many applications for other high frequency radio work. The calibrator is a small crystal oscillator unit having fundamental frequencies at 250 and 2000 kilocycles. Harmonics of these frequencies are such as to provide exact calibrating frequencies for use in all high frequency work. It is accurate to the degree of plus or minus .05%. The unit is complete with its own power supply and acorn type oscillator tube. Selection of either fundamental frequency is obtained by a two-way switch. An output jack has been included for ease of connection.

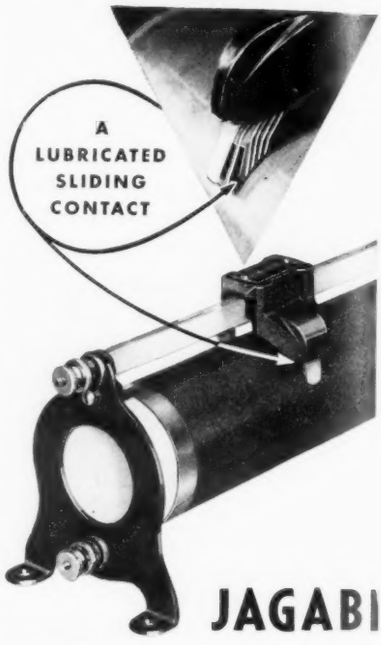




The 5-inch oscillograph gives a large image of unusual clarity for the finest work. All controls are located on the front panel, and a special step-attenuator is provided to prevent changes in frequency characteristics at various input levels. Provision is made for synchronization on positive or negation peaks, an important feature because in certain television tests it is desirable to choose which is to be used.

When the new alignment oscillator is used with a cathode ray oscillograph, the selectivity curve of the circuits under test is produced on the television screen. Operation of the new instrument is surprisingly simple. There are only four highly-accurate, easily read controls: the power selector switch for i-f or r-f operation; two range switches for selecting the desired i-f and r-f channels; and the phase control and switch for adjusting the oscillograph horizontal deflection to provide single image operation. The output frequency sweeps through the r-f and i-f bands at a rate of 60 times per second, providing a steady, non-flickering pattern on the oscillograph screen. R-f and i-f coaxial transmission lines with proper terminating loads are included.—*RCA Mfg. Co., Camden, N. J.*

NEW!



JAGABI

"Lubri-tact"

RHEOSTATS

at new LOWER prices

In our constant efforts to improve Jagabi Rheostats, we have now introduced a *lubricated sliding contact*, which we believe to be the most important single improvement to our rheostats during the past 30 years.

This new feature, which we call "Lubri-tact"—from *lubri*cated con*tact*—eliminates scratching and abrasion and introduces a smoothness of fine adjustment that is remarkable. The electrical contact is actually improved and, because of the graphite lubrication, wear on brushes and winding is reduced to a minimum.

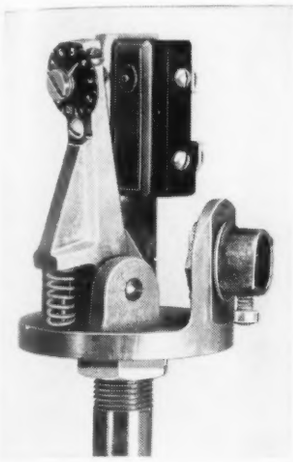
Bulletin 1620-I describes this new improvement and also lists new lower prices. Write for a copy.

JAMES G. BIDDLE CO.

ELECTRICAL INSTRUMENTS

1211-13 ARCH STREET PHILADELPHIA, PA.

Why Guess at . . .
CONTROL or LIMIT TEMPERATURES



HEAT CONTROL

Temperature Range Minus 100 to 600° F.
Other models to 1400° F.
Differentials ± ¼ deg. to ± 5 deg. F. Will give accurate control in ovens, tanks, incubators, water baths, dryers, chemical processes, and air ducts.
Send for Bulletin V-I.

BURLING INSTRUMENT CO.
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NEWARK, N. J.

CLARE RELAYS
ELECTRONIC — INDUSTRIAL

Individualized to meet your specific instrument design specifications.

Clare Relays are available in innumerable coil, contact, adjustment and timing combinations — accurately made of quality material.

Clare engineers welcome an opportunity to assist you in your problems. Personal attention will be given your inquiry.

CLARE ELECTRO MECHANICAL SPECIALTIES RELAYS

Write for CLARE RELAY LITERATURE

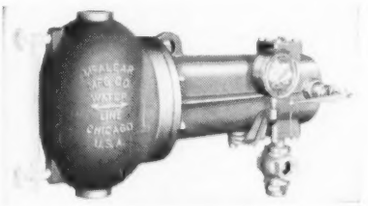
C. P. CLARE & CO.
LAWRENCE & LAMON AVES. - - CHICAGO
15 East 26th St., New York City

Recorder-Controller for Throttling Electric Heat

An economical means for obtaining accurate control of electric furnaces and ovens without the use of rheostats, transformers or other expensive equipment, is said to be provided in a new recorder-controller for throttling electric heat recently developed. The instrument has no measurable controller "dead zone" and will hold a steady temperature instead of the oscillating temperature of "on-off" or two-position control. The new recorder-controller is similar to the company's line of potentiometers with the exception that by reciprocating the control contacts throttling regulation of electric heat is obtained. When the temperature is far below the desired control point, as for example in starting, the recording carriage indicating the furnace temperature does not engage the reciprocating control mechanism and therefore the power supplied to the furnace is on 100% of the time. The action of the instrument is such that the recording carriage comes to rest in a position which balances the heat input against the heat loss. The throttling zone can be adjusted readily within wide limits and load error kept within a few degrees without introducing appreciable hunting. Adjustment for load error is provided.—*C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.*

Feed Water Regulators

A series of improved feed water regulators for steam boilers has been designed not only to maintain a constant, safe water level automatically in any steam boiler, whether operated singly or in batteries, but also to prevent damage by stopping burners or stokers when, in case of failure of the water supply or pumps, the boiler water level reaches a dangerous point. Regulator No. 906 maintains proper levels in individual boilers supplied by steam pumps which are controlled by governors. One or several boilers may be supplied by a single pump, but each boiler comprising a battery thus supplied should be individually equipped with a regulator. All regulators in this series are constructed of semi-steel with stainless steel float and trim for pressures up to 250 pounds, and of cast steel with stainless steel float and trim for pressures of over 250 pounds.—*McAlear Mfg. Co., 1901-1907 S. Western Ave., Chicago, Ill.*



A VALUABLE AID FOR YOUR LABORATORY
. . . and an unusual value!
RCA 5-inch Oscillograph

You'll call this RCA 5-inch oscillograph a worth-while addition to your laboratory.

It embodies all of RCA's skill and experience in oscillograph manufacture. And in addition to performing all the laboratory functions of other RCA Oscillographs, it may also be used for engine pressure measurements and similar applications.

It offers you unusually wide amplifier ranges and its 5-inch screen is easy to read. All controls are conveniently located on front panel. Compact construction assures easy portability. An unusual value at its moderate price. Stock No. 160, net price $130.

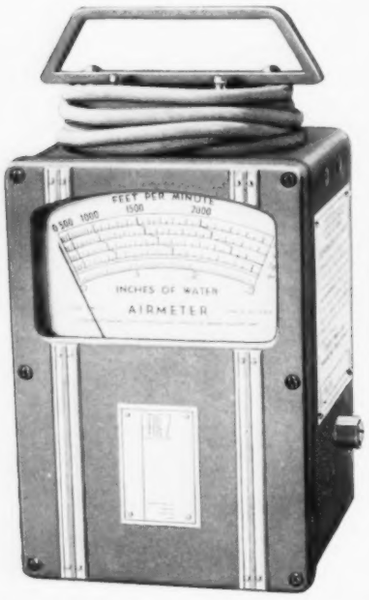
Over 345 million RCA radio tubes have been purchased by radio users . . . in tubes, as in parts and test equipment, it pays to go RCA All the Way.

RCA **Test Equipment**

RCA Manufacturing Co., Inc., Camden, N. J.
A Service of the Radio Corporation of America

Airmeter

This new instrument for the measurement of static pressures, air velocities and stack drafts directly from a pointer and graduated scale is illustrated. The Airmeter has a pressure range of from 0" to .3" of water, and a velocity range of from 300 to 2,000



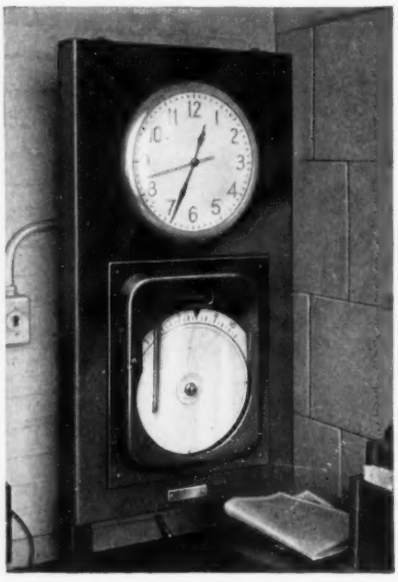
feet per minute. The Airmeter is unique in that the velocity scale is divided into four banks, each calibrated for a typical air temperature, and readings at other temperatures can easily be interpolated over the entire range. The instrument is protected by a steel slip-over cover (8¼" × 4¼" × 5½" wide), and finished in an attractive Gunmetal color.—*Julien P. Friez & Sons, Baltimore, Md.*

Self-Balancing Potentiometer Controller

The instrument is designed to indicate temperature at all times on a 10-inch scale. The control point is adjusted by means of the knob shown just to the right of the standardizing knob in the upper left-hand corner of the door frame, and is readily visible. This arrangement permits the comparison between the control setting point and the temperature indicator. Like all other models of the Celectray potentiometer

line, this instrument utilizes a beam of light, a mirror galvanometer and a phototube, which allows for a unit constructional design where there is no motion unless the temperature is changing. A special arrangement of lighting the scale is accomplished by using a Lucite rod that carries the illumination from the same source of light that is used to determine the galvanometer position.—*C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.*

Any Distance From Pipe Line Without Sacrificing Accuracy



USE of a Cochrane Electric Flow Meter permits installation of the instrument at any distance from the pipe line, without sacrificing accuracy. *Write for Bulletin 2096.*

COCHRANE CORP., 3120 N. 17th St., Phila., Pa.

COCHRANE
FLOW METERS

SCHOTT & GEN. JENA

JENA KPG ALL-GLASS STIRRER

For stirring contents of flasks under low pressure or vacuum

Replaces clumsy mercury seal. No supplementary seal or stuffing box needed. Pressure differences as great as 100 mm. of mercury between inside and outside of flask cause no leakage.

Recommended for all types of chemical work, particularly for organic, electrochemical and physical research.

Leaflet JS 262 on request

Jena KPG Precision Bore Glass Tubing

Available in two types: bore accurate within ± 0.01 mm.; for extreme accuracy, within ± 0.001 mm.

Bores from 0.5 mm. to 60.0 mm. Lengths up to 1 meter. Inside surface clear like regular transparent glass tubing. Bore of any cross section: round, square, oval, conical, etc.

For barometers, viscosimeters, pipettes, syringes, flow-meters, colorimeters, etc.

Bulletin 4548-E on request

At leading laboratory supply dealers

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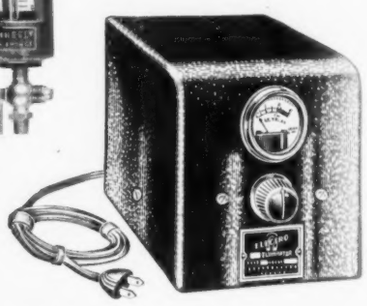
Jena Glass Works, Schott & Gen.

Fish-Schurman

Pressure Gage

A new mercury pressure g[a]ge has a body of cast semi-steel, [a] the tube, an unbreakable gl[a]ss substitute is used, threaded [di]rectly into the casting, to eli[m]inate glands or packing. The bla[ck]-etched aluminum scale, gradua[te]d from 0-3½ lbs. on one side a[nd] 0-56 ozs. on the other, provi[de] wide angle visibility. — *Connelly Iron Sponge & Governor Co., 31[5]1 S. California Ave., Chicago, Ill.*

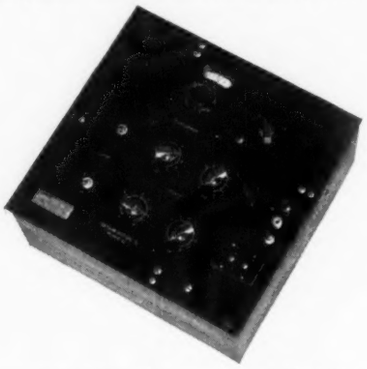


Re-designed Eliminators

New models of eliminators have all wiring and terminals at the rear. This restyling has been carried out in Model E silent 1.4-3 volt AB eliminator, Model G, six-volt A eliminator, and Model J, AB eliminator for use with any 6-volt d-c. power source.—*Electro Products Labs., 549 W. Randolph St., Chicago, Ill.*

Regional Spectrophotometer

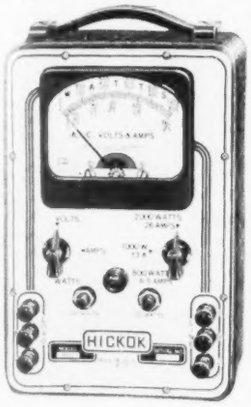
The feature of this device is that the color absorption of liquids can be determined by an electric eye for each narrow region of the spectrum, including the regions far into the infra red and ultra violet which are invisible to the human eye. Extremely small impurities in a liquid may be detected by the variation in the characteristic absorption curve which can be plotted from the readings obtained from the Spectrophotometer. Thus in canned foods and beverages, minute quantities of lead, copper and other foreign substances which are poison may be discovered more readily



than with the ordinary methods of chemical analysis. The concentration of liquids as evidenced by color absorption may be quickly and accurately determined. The range of the instrument being far beyond the visible spectrum, 350 millimicrons to 1000 millimicrons, permits investigations of color absorption characteristics which heretofore have been practically impossible.—*Coleman Electric Co., Inc., 310 Madison St., Maywood, Ill.*

NEW HICKOK

VOLT—AMPERE—WATTMETER
A.C. CIRCUIT ANALYZER



Measures Load Values of Volts, Amperes and Watts

Full Coverage Ranges—

WATTS:
0-20-500-1000-2000 Uniform Wattmeter Scale

CURRENT:
0-260 m.a.—6.5 - 13 - 26 amps.

VOLTS:
0-130-260

Also tests electrical appliances from clocks to cooking ranges operating on the three wire Edison System. All necessary leads and connectors available.

This is just one of the many types of Hickok built electro-dynamometer wattmeters.

Write for Bulletin 900.

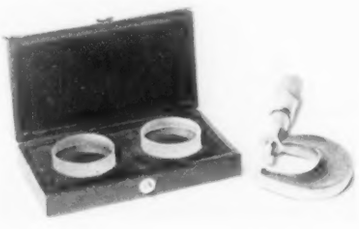
ADDRESS ALL INQUIRIES TO
THE HICKOK ELECTRICAL INSTRUMENT CO.
10514 DUPONT AVE. • CLEVELAND, OHIO, U.S.A.

Appliance Type Wattmeter

To fill the need for a wattmeter particularly adapted to household appliance testing, brought out a modification of its "Steel-Six" wattmeter and embodied in the design several features which will commend the instrument to those having occasion to check up current consumption on electrical household equipment. The instrument is 6" square x 4" deep. Scale length is 5-3/16". Accuracy is ½ of 1%. Two ranges, 0-250 watts, 0-750 watts. Voltage 110 and 220.—*Roller-Smith Co., Bethlehem, Pa.*

Optical Parallels

A set of optical parallels for checking the flatness and parallelism of faces of micrometers, measuring machines and instruments includes two parallels. The parallels are 1¼" diameter and are accurately flat and parallel within 5 millionths of an inch. One parallel is approximately .650" in thickness and the other is approximately .6375", or .0125" less. The .650" thick parallel checks the parallelism of the anvil and spindle faces with the spindle in the same angular position as at zero. The .6375" parallel checks the parallelism of the two faces at ½ turn or 12½ thousandths away from the zero position. Thus, while the anvil and spindle may show perfect parallelism at zero, the other parallel will show any lack of squareness of the spindle face when it is moved around ½ turn from the zero position. The meaning of the interference bands which will be seen when the micrometer faces are brought in contact is easily understood. Contact will be made on the glass parallel at the two nearest points on the anvil and spindle face, and the number of interference bands that occur on each face tell how much that face runs off from the contact points in units of .00001". (The sum of the number of bands occurring on each micrometer face gives the total error of parallelism.) If the two faces are perfectly flat and parallel, one broad or continuous band will form across both faces. On new or relapped micrometer faces the interference bands may be easily seen in diffused daylight. A monochromatic light may be required to show the bands on worn faces.—*Van Keuren Co., 12 Copeland St., Watertown, Mass.*



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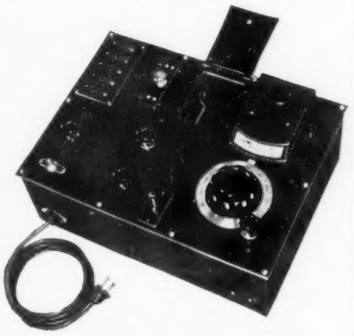

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For plane parallel sample holders up to 6" long. Adapters available for test tubes and micro tubes.

No batteries. Operates from 110 V. line. Fully balanced for line voltage variations and for spectral changes of lamp.

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Rubicon MULTIPLE REFLECTION galvanometers have recently been much improved through redesign of optical system. The definition of the line-image is now so sharp that readings can be estimated to .1 of a millimeter division.

These sturdy self-contained galvanometers are available with sensitivities as high as 5 x 10^{-10} ampere and 1 x 10^{-6} volt per millimeter division.

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Electrical Instrument Makers
29 North 6th St. Philadelphia, Pa.

Galvanometers, Electrometers, Potentiometers, Colorimeters, Wheatstone & Kelvin Bridges, Resistance Standards, Resistance Boxes, Coil Testers Clip-on Ammeters, etc.

Time Delay Relay

The Model 308 Time Delay Relay is used for automatically timing the duration of a process cycle. It comprises a synchronous timing motor driving a gear train through a magnetically engaged clutch. At the end of the timing period, a switch operates to stop the timing motor and either connects or disconnects the load as desired. Upon breaking the timer circuit the magnetic clutch releases and the timer automatically resets itself. The timing is easily adjusted

by setting the knob and pointer to the desired time on the calibrated scale. As the timing period elapses, the pointer travels over the scale and indicates the amount of the timing period remaining. Three timing ranges are available in all Models: 0 to 5 min., 0 to 50 min., or 0 to 5 hours.—*Part-low Corp., 12 Campion Road, New Hartford, N. Y.*

Five Inch Oscillograph

A low cost 5-inch cathode ray oscillograph which may be used for a wide variety of experimental and test applications in school and industrial laboratories provides an instant picture-record of many recurrent electrical phenomena. This new general purpose oscillograph is an instrument of great value in electronic and acoustical studies. In addition, it may also be used for engine pressure measurements and analysis of other mechanical devices. In mechanical vibration studies, the instrument is used in conjunction with the RCA vibration pickup, which converts any recurrent mechanical motion into electrical currents of identical characteristics. These electrical currents are presented visually on the os-

cillograph screen. Uses of the oscillograph in this field include studies of vibrations of motors or motor parts, vibrations of wings of aircraft, vibrations of buildings and foundations, frequency and force of air hammers, and components of machines causing noise. The 5-inch tube used provides a large, well defined trace for analysis purposes.—*RCA Mfg. Co., Camden, N. J.*

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The TABER V-5 Gauge determines initial and basic stiffness, also creep under sustained deflection. Direct reading: Standard Metric calibration. Range: 0 to 2000 gram centimeters. Prices: $125.00 to $140.00. Write for illustrated bulletin No. 3802.

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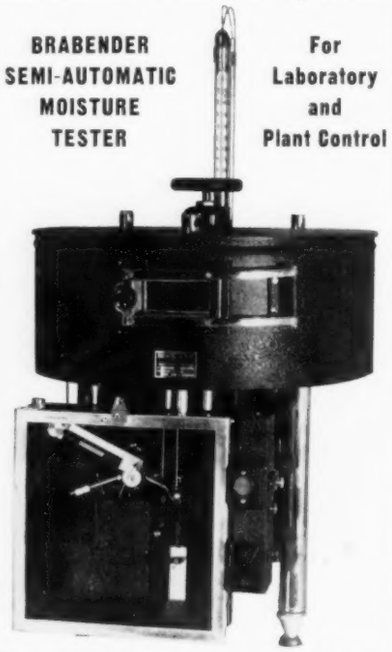
BRABENDER SEMI-AUTOMATIC MOISTURE TESTER

For Laboratory and Plant Control



An ideal combination of drying oven and analytical balance. Requires no training—just push down a lever and read the moisture loss from an illuminated dial—directly in percentages.

Accuracy—1/20th of one percent. Capacity—Ten 10-gram samples. Temperature Range—85° C.-175° C. Moisture Range—0%-100%. Heating Capacity—750 Watts—10 Minutes. From Room Temperature to 130° C. Operating Current—110 volts, 60 cycles, AC.

BRABENDER CORPORATION Rochelle Park New Jersey

Type 50 Variac

The newest addition to the line of General Radio Variacs is the Type 50, available in a 115-volt model at 5 kva and in a 230-volt model at 7 kva. These are continuously variable auto-transformers intended for industrial applications. Particular applications include the control of speed in electric motors, of heat in electric furnaces, and of illumination in lighting systems. Both models can be connected to give output voltages 17.5% above line voltages: 0 to 135 volts for the 115-volt model and 0 to 270 volts for the 230-volt model. Ratings are for 60-cycle service, but Variacs can be operated at 50 cycles with slightly greater heating and slightly reduced rating.

The mounting is arranged so that the Variac can be built into larger equipment or used on the laboratory bench. Two or more units can be ganged for operation on polyphase systems.—*General Radio Co., 30 State St., Cambridge, Mass.*

A. C. Break Down Tester

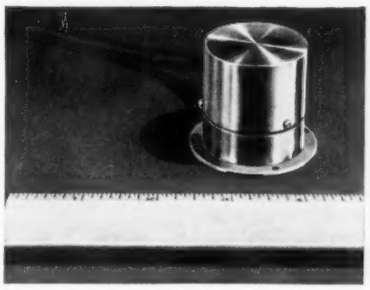
The Model 400 high voltage breakdown equipment, meeting the A.I.E.E. specifications for high voltage testing, is self contained but powered from a 115 volt, 60 cycle single phase power supply. It has a range of 0-3000 volts with a secondary current of .500 milliamps.—*Associated Research, Inc., 16 N. May St., Chicago, Ill.*

Rufometer

A new instrument known as the Rufometer and designed to register bumps per mile depends for its measurement on the vertical motion imparted to the vehicle body by the irregularities in the road surface. In the construction of the modern car, many of the undesirable irregularities of the road surface are absorbed in the car springs, and the car body assumes a vertical motion of long period relative to the road surface, while the wheels and the knee action mechanism closely follow the actual contour of the road. The pen arm is about 6" long and carries a small standard type fountain pen at its lower end. The pen point thus makes a movement either to right or left of a neutral position, directly proportional to the displacement of the car body with respect to the knee action arm. The numerical integrator consists of a small counter and an over-running clutch connected to the recording pen. This clutch is so constructed that it will drive the integrator in one direction proportional to the pen movement thus integrating the movements of the pen, however small.—*Dow Chemical Co., Midland, Mich.*

Moving Coil Vibration Pick-Up

Type RA-278



The RA-278 Vibration Velocity Pick-Up is of special interest to the aircraft and automotive industries. It also has application to engineering and production testing problems in many other industries.

Being an inertia type pick-up operating on the moving coil principle, the RA-278 has the stability characteristic of Western Electric microphones in acoustic testing work. In addition, it gives you flexibility of application heretofore unknown in vibration testing.

1. Calibration stability—Independent of temperature, humidity or other conditions surrounding test.

2. Wide frequency range—Measurements of vibration down to 5 c. p. s. or below, possible in conjunction with suitable instruments.

3. Sensitivity—Far in excess of any requirements encountered in automotive or aircraft work.

4. Light weight—Total weight less than four ounces, minimizing damping effect on surface under test.

5. Convenience—Can be used in any position, with or without probe.

6. Ruggedness—Being entirely enclosed, there is nothing to be broken or damaged—cannot be injured by excessive amplitude.

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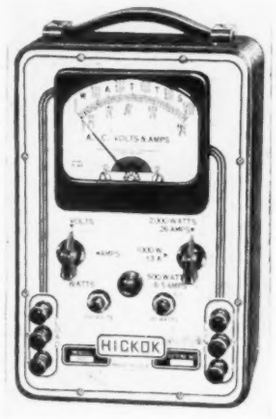
Appliance Tester

This new tester has 10 ranges of a.c. volts, amperes and watts. While designed primarily for electrical appliance testing it is also useful for radio as the wattmeter checks a.c. sets. Model 900 is especially valuable for a.c. trouble finding as it tests appliances while in actual operation, indicating wattage consumption, amperes and line voltage. Being completely encased in steel, it may be used around heavy current carrying conductors without danger of stray field errors. Has four ranges of watts up to 2000, four ranges of current to 26 amps. and two ranges of volts 0-130-260. A Dynamometer meter with a specially designed current transformer is employed with suitable switching to obtain these ranges. Provision has been made for testing in two and



three wire circuits. Detachable leads are furnished for connection to small appliances. Low range of 0-20 watts will measure power consumed by appliances, which remain on the line permanently. A fuse protects this range from overload. The high range is suitable for checking on the three wire 220 volt system. Available in 60 and 25 cycle models.—*Hickok Electrical Inst. Co., 10514 Dupont Ave., Cleveland, Ohio.*

Heavy Duty Selenium Rectifier

A new line of industrial rectifiers employ a new rectifying medium, selenium plates, which operate on a principle similar to that of other dry plate type rectifiers. Selenium rectifiers are manufactured to order in full wave bridge or half wave types, for practically any desired d.c. voltage and current output. The rectifier elements, transformer, fuses and controls are mounted in ventilated steel cabinets. Control is effected through dial tap switches. Transformers are equipped with low voltage primary taps, or voltage stabilized transformers can be furnished to order. Both primary and output circuits are fused. Standard types are normally furnished with d.c. voltmeter and ammeter, but other meters can be included to specification. This type of rectifier can be supplied for practically any industrial direct current requirement where other types of rectifiers or motor generator sets are commonly used. This includes magnetic chucks and clutches, lifting magnets, elevator, machine tool and other d.c. controls, solenoid valve operation, prevention of electrolytic corrosion, battery charging, operation of isolated d-c. motors, circuit breaker operation, alarm, signal and communication systems.—*Fansteel Metallurgical Corp., North Chicago, Ill.*

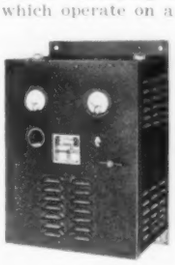
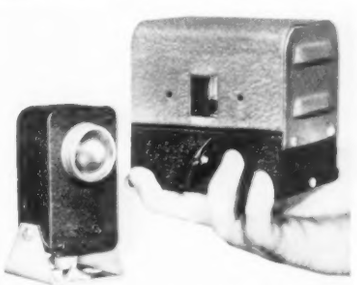


Photo-Electric Control

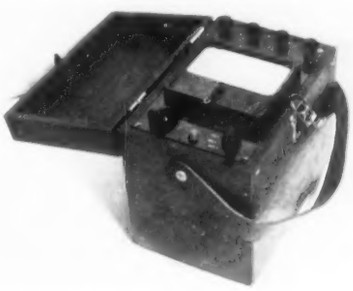
Control operates on 110 volts, 60 cycle only. Current supply to the light source (6 volts) is supplied from the transformer within the control. Power relay is designed



for 3 amps., non-inductive loads. Potentiometer adjustment permits compensation for various degrees of light intensity to photo-cell.—*United Cinephone Corp., 43-37 Rawson St., Long Island City, N. Y.*

Insulation Resistance Tester

The Vibro-test is intended primarily for testing insulation values of wires, cables, generators, motors, wherever it is desirable to determine high resistance insulation values. The following ranges are provided:



0-200 megohms at 500 volts; a separate resistance range ¼ to 2000 ohms; and voltage ranges 150-300-600 volts, a. c. and d. c. —*Associated Research, Inc., 16 N. May St., Chicago, Ill.*

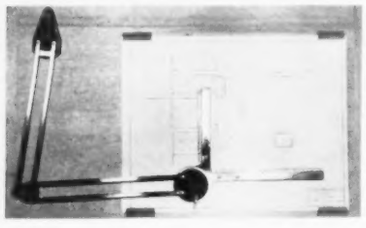
Dynamic Mutual Conductance Tube Tester

This new instrument measures the dynamic mutual conductance on three ranges of micromhos—0-3,000; 0-6,000; 0-15,000. It has a five-inch rectangular meter—accuracy 1½%—with longest scale available. It tests all Octal, Loktal and Ballast tubes, all filaments to 110 volts in consecutive steps; also

pilot lamps. Besides giving readings in micromhos the dial indicates, "Good, Bad, Doubtful." Diodes are tested separately for emission. In addition to the complete tube testing section this instrument has an accurate set testing section with four uniform ranges of a.c. and d.c. volts, d.c. milliamperes, ohms to 25 megohms in three overlapping ranges (no batteries used) and capacity to 24 microfarads in overlapping ranges. Leaks in electrolytic condensers are checked with polarizing voltage. Electronic rectifiers are used in a.c. volts thus avoiding rectifier troubles. The instrument has engraved metal panel and is enclosed in a portable case 14" x 13¾" x 6".—*Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, Ohio.*

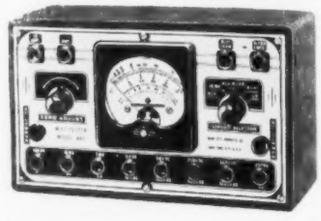
Portable Drafting Machine

The Model D-520 drafter is equipped with an Exclusive type of Wrigraph adjustable ball bearing which increases the accurate life of the machine. This model will make drawings 20" × 26" or smaller, and is furnished with a special "tack on" mounting plate so that it can be instantly fastened to any flat wooden surface and in any position. The protractor is of the one degree indicating type and a new kind of transparent edge, engine divided scale is used. Scales are interchangeable on the protractor head and all standard graduations are available. The entire machine can be knocked down and carried in a brief case.—*L. G. Wright, Inc., 5209-36 Euclid Ave., Cleveland, O.*



Multimeter

A new a-c.-d-c. multimeter incorporates the functions of 25 different instruments in a single unit which is completely self-contained in a 3" × 8½" × 5" case and weighs but 2¼ lbs. This Multitester provides the following measurement ranges: d-c. volts 0-5/50/250/500/2500; d-c. milliamps. 0-1/10/100/1000; d-c. amps. 0-10; a-c. volts 0-10/100/500/1000; output—4 ranges same as a-c. ranges; ohms 0-500/100,000/1 meg.; special low ohms range provides readings as low as 1/10th ohm in low current drain meter circuit arrangement; decibels minus 8 to plus 15, plus 12 to 35, 26 to 49 and



32 to 55. The multi-scale meter which constitutes the heart of this instrument is one of the 3" square Bakelite case type with D'Arsonval movement and provides sensitivity of 1 milliamp. or 1000 ohms per volt; accuracy 2%. Around this on the attractive panel are the various test-prod jacks, function-selector switch, and zero-adjustment control, each clearly labeled.—*Radio City Products Co., 88 Park Place, New York, N. Y.*

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TEMPERATURE CONTROL
MODEL M, INDICATING
Three Ranges: 50 to 350; 100 to 650 and 100 to 1,000 Deg. Fahr.
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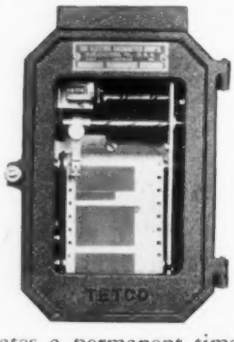

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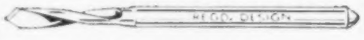

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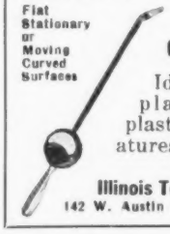

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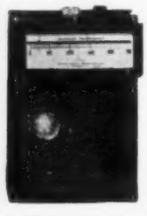
PYROMETER CONTROLLER



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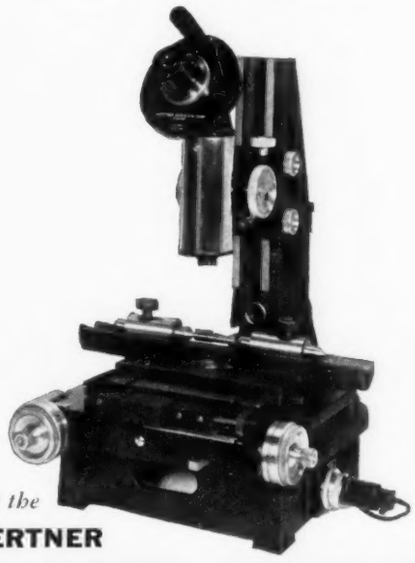

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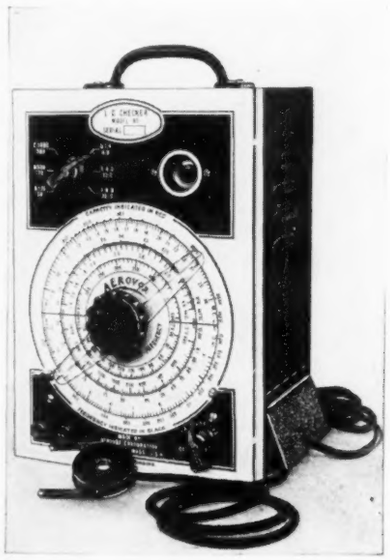
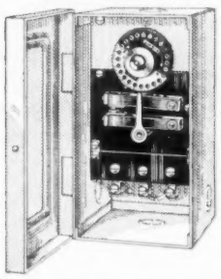
Testing Condensers and Inductances Under Operating Conditions

A radically new means of testing condensers and inductances in the radio-frequency range under conditions that simulate actual operating conditions, is now offered in the Aerovox Model 95 L-C checker. The instrument is entirely self-contained except for the 110-volt a-c. or d-c. power supply. It comprises an oscillator covering 60 kc to 26 mc in 6 coil ranges, together with a frequency-matching indicator. The coil ranges are selected by the coil-range switch, as follows: Range A, 60-170 kc; B, 170-490 kc; C, 490-1500 kc; D, 1.5-4.6 mc; E, 4.5-15 mc; and F, 13-26 mc. The frequency dial is directly calibrated in frequency for each of the six ranges, and calibration should be accurate to 1% or better. The shadow angle of a "magic eye" Type 6E5 tube is used to indicate the amount of energy in the oscillator circuit, and this angle widens when the oscillator is coupled to a tuned circuit of the same frequency as the oscillator. The dial is also calibrated in capacity from .0004 to 1 mfd. with an accuracy of ± 10%. Capacitors below .0004 may be read in several ways by the use of a coil or an additional condenser.—*Aerovox Corp., New Bedford, Mass.*



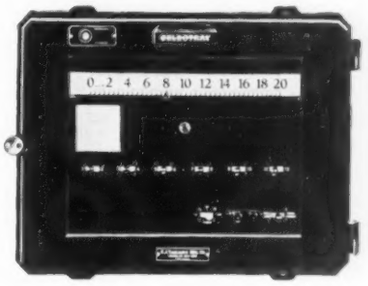
Time Switches

For automatically controlling electrical circuits for timed operations, a new timer in a neatly styled steel cabinet with concentric knockout in top, bottom, back and sides, is illustrated. It has a synchronous motor, self-starting, sealed in lubrication, pure silver, on copper button type contacts securely mounted on Bakelite contact arms. New quick make and quick break switch action, mechanically operated by the motor driven clock movement produces a "Wipe-Action" before contact is broken. Terminal Block equipped with solderless lugs, handy for quick secure wiring.—*Wadsworth Electric Mfg. Co., Inc., Covington, Kentucky.*



Multiple Point Self Balancing Indicator

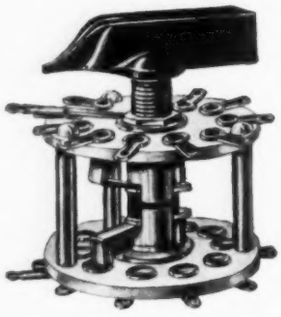
A new self-balancing indicator, multiple point is supplied in three models: Hair-Line Indicator designed to cross ten inches of scale in ten seconds. This model is ideal for applications where a large number of temperatures is to be measured. The indicator will balance on successive points more rapidly than an operator can record them. An "in balance" signal light is provided which lights when the carriage travels from one point to the next, flickers when it steps into



balance, and stays out when it is time to take the reading. Two other models are available: one having 22 secs. for the carriage to cross the scale; the other, requiring 45 secs. Another feature is the special arrangement of lighting the scale, which is accomplished with the use of a Lucite rod which carries the illumination from the same source of light that is used to determine the galvanometer position. A switch box or combination of switch boxes, of the same design as the instrument case, can be supplied for an unlimited number of points. —*C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.*

SOLID SILVER CONTACTS
ROTARY SELECTOR SWITCHES

1 TO 24 POINTS



Contact resistance approximately 0.0005 ohms can be furnished in cast aluminum box with marked bakelite panel.

Send for Bulletin #500 HL

SHALLCROSS MFG. COMPANY
COLLINGDALE, PA.

Statement of the Ownership, Management, Circulation, etc., Required by the Act of Congress of March 3, 1933, of *Instruments* published monthly at Pittsburgh, Pennsylvania, for October 1st, 1939.

State of Pennsylvania, County of Allegheny, (ss).

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Richard Rimbach, who, having been duly sworn according to law, deposes and says that he is the Publisher of *Instruments* and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, Postal Laws and Regulations, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business manager are:

Publisher, Richard Rimbach, Pittsburgh, Pa. Editor, M. F. Behar, Pittsburgh, Pa. Managing Editor, Richard Rimbach, Pittsburgh, Pa. Business Manager, Richard Rimbach, Pittsburgh, Pa.

2. That the owners are: Instruments Publishing Co., Pittsburgh, Pa.; M. F. Behar, Pittsburgh, Pa.; Jackson Burgess, Freeport, Illinois; R. K. Farnham, New York, N. Y.; William Farnham, Chicago, Illinois; C. E. Seibert, Pittsburgh, Pa.; Richard Rimbach, Pittsburgh, Pa.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

Richard Rimbach, Publisher

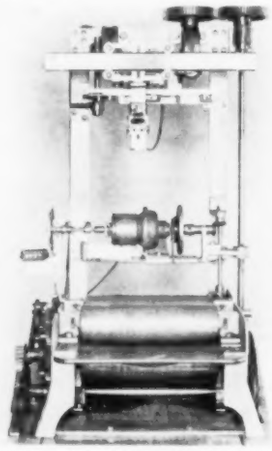
Sworn to and subscribed before me this 6th day of October 1939.

[SEAL] Edward M. Seibert, Jr.

(My commission expires March 24, 1941.)

Area Calculator

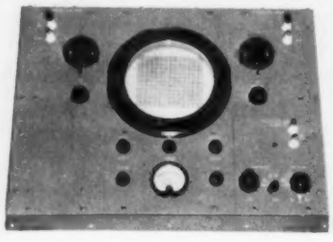
The area calculator is a device using a scanning beam and photo cell for purposes of obtaining exact measurements of area in square inches and tenths and square feet and hundredths of irregular patterns or any irregular plane surfaces regardless of length or width.



The work piece to be measured enters revolving rolls and is carried across the measuring plane which is composed of a mirror, and above this travelling back and forth is a carriage holding a light source, optical system and light chopper on one side and a photo electric cell on the other. The mirror in the measuring plane is tilted at a slight angle so that the measuring beam is reflected to the photo cell. The track in which the carriage runs holding the light source, photo cell, etc., is operated by a cam which functions in a manner so that at all times, regardless of the travel of the work piece through the rolls, the path formed by the beam of light is at exact right angles. Therefore, every part of the work piece is scanned and contiguous parallel paths result. There are of course proper amplifying circuits, magnetic clutch for the counter and a regular commercial counter is used on this particular model. The feature of this machine is accurate measurement for actual edge to edge cutoff of the work piece as well as the fact that every portion of the work piece is scanned. This device is particularly desirable for exact measurements of long patterns and irregular surfaces such as hides, etc. It is also desirable in the measurement of small patterns and for obtaining exact percentages of waste in the layouts of small patterns on either regular or irregular material. That is to say, a number of try-outs could be made using small patterns in different layouts and that layout showing the least percentage of waste would naturally be the one to use for efficient and scientific production.—*Stockton Profile Gauge Corp., 165 Jackson St., Lowell, Mass.*

Oscilloscope For Television

An oscilloscope, suitable for the study of wave shapes and transients, the measurement of modulation, the adjustment of radio and television transmitters and receivers, the study of the phase shift in amplifiers and the measurement of voltage amplitudes, operates from 110 volts, 60 cycles, and uses a nine-inch cathode ray tube. A complex sinusoidal signal of one-fourth volt at any frequency between 10 cycles and 4 megacycles per second will produce a deflection of more than 4" from peak to peak on the cathode ray tube. Provision has been made for extremely large deflections when these are necessary. Any single sine wave frequency between 5 cycles and 6 megacycles per second may be shown in graphical form. The horizontal sweep circuit operates over a range of from 10 to 100,000 cycles per second.—*General Electric Co., Schenectady, N. Y.*



Solutions Tester

The RD-1 Solu-Bridge is an economical solutions conductivity tester. It is primarily designed to determine the concentration of alkali washing solutions of the type generally used in the dairy, brewery and soft drink industries, as well as in the field of metal products when surfaces must be cleansed. The panel scale of the bridge is calibrated in percentage of sodium hydroxide, so that measurements are directly and easily obtained, without the necessity of referring to complicated graphs or charts. —*Industrial Instruments, Inc., 156 Culver Ave., Jersey City, N. J.*

An Automatic CO_2 Compensator For Cupola Control

By F. K. VIAL

Vice President in Charge of Research,
Association of Manufacturers of Chilled Car Wheels, Chicago, Ill.

This paper received the First Prize in the First Annual Instrumentation Contest

NO metal melting device can compare in efficiency with the cupola or blast furnace. It has no "competition." Where competition is not a factor there is a natural resistance to any change in procedure. This is true of the cupola. Its control still depends on the operator's skill. Little productive research has been put forth upon cupola control methods, although text books have referred to the value of combustion analysis and frequent mention is found of the experiment of Belden back in 1913.

Elaborate computations have been made by the Association of Manufacturers of Chilled Car Wheels to set forth the principles of cupola melting, and exacting heat balances compiled; and now the first practical efforts are being put forth to improve the control of the cupola.

There are three general objectives in cupola practice: (1) Control of chemical analysis; (2) Control of iron temperatures; (3) Economy in the use of materials. The control of each of these three items is based on maintaining the proper ratio of air per minute to coke consumption.

All chemical changes such as oxidation loss and carbon pick-up, and physical factors such as temperature and time of tapping, are directly related to the combustion in the cupola. By analyzing the gaseous products of combustion we can obtain indices of the reactions taking place. Variations with CO_2 content are illustrated in the following table:

% CO_2 in evolved gases	8%	16%
Lbs. Air	2200	1500
Lbs. Coke	300	150
BTU. developed	2,262,000	1,677,000
BTU. absorbed	1,040,000	1,040,000
Flame temperature	3060°F.	3380°F.
Efficiency of combustion	58.0%	86.0%
Cupola efficiency	26.6%	53.4%

On the basis of one ton of metal melted.

The temperature of the metal depends on the amount of, and rate at which, heat is developed in the combustion zone —hence on the time ratio of air to coke in various stages of combustion. Each stage of combustion is indicated by the percentage of CO_2 in the gases of combustion. The usual range in cupola practice is from 10% to 15% of CO_2. The heat produced from a pound of coke ranges between 7400 BTU's at 10% CO_2 and 9800 BTU's at 15% CO_2.

Cupola practice requirements differ from others: Usually either the highest CO_2, as in boiler operation, or the lowest CO_2, as in the producer gas industry, represents the maximum operating economy. In the foundry, control at *both ends* of a limited range of CO_2 content is necessary for optimum results.

Two Opposing Factors

The higher percentages of CO_2 not only signify a greater quantity of heat but also a higher temperature, and higher temperatures insure a higher ratio of transfer of heat from the gases to the iron, hence the economy in coke is based on regulating the stage of combustion.

However, in order to maintain this higher percentage of CO_2 throughout the entire heat, it is necessary to run a low coke ratio. Under such conditions, the silicon oxidized will be high. Hence, there are two opposing factors: economy of coke and economy of silicon. Regulation to obtain the proper balance that will give the desired temperature, normal oxidation loss, with maximum economy, predicts the regulation of the stage of combustion.

The optimum stage of combustion at which to operate depends on the type of coke. With soft easily-consumable cokes that produce considerable gas, it is necessary to run a lower CO_2 and a higher coke ratio. With harder cokes, a lower coke ratio and a higher CO_2 give best results. To balance the rate of air supply for a given grade of coke, and to detect differences in cokes accurately, CO_2 measurements are necessary.

Information obtained from instruments gives the cupola foreman a definite foundation upon which to base his judgment; and results in a higher grade of cupola operation than is possible without instrumental guidance.

Fig. 1 shows the relation of economy to stage of combustion for hot blast cupolas upon which the development of the CO_2 recorder is being pushed forward. On this chart the losses of manganese and silicon are plotted against stages of combustion and cost of coke used. At the top of the chart the cost summations are plotted, two different element analyses being represented.

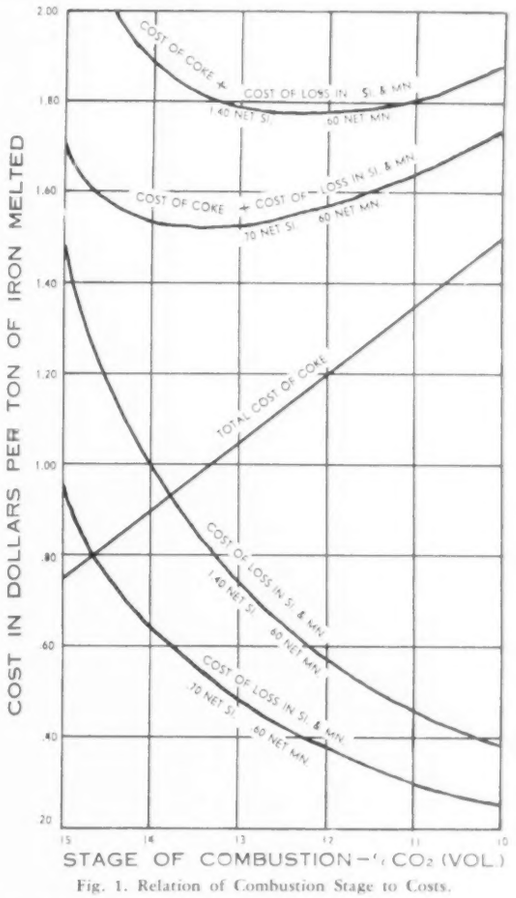


Fig. 1. Relation of Combustion Stage to Costs.

This chart brings out the economic necessity for close control of combustion. For example an increase in CO_2 from 13% to 15.5% involves an additional cost of $0.20 per ton of iron melted. Twenty cents is pocket change, but think of

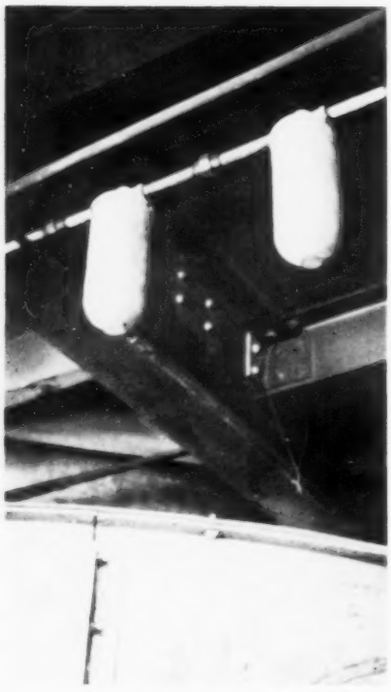


Fig. 2. Gas Filters

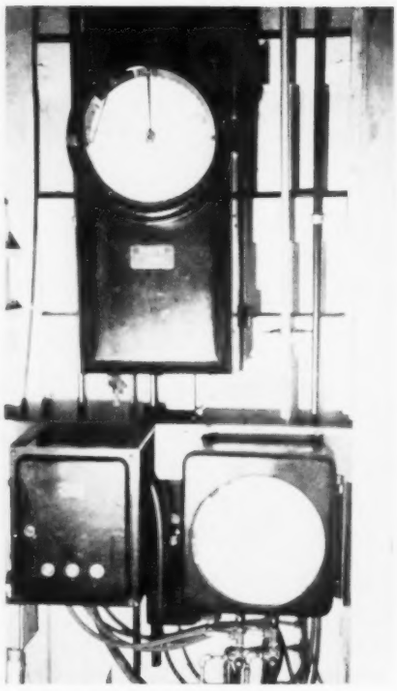


Fig. 3. CO_2 Recorder, Volume Recorder and Compensating Control.

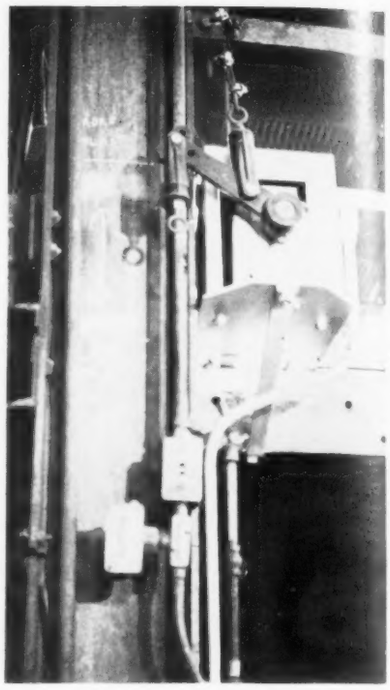


Fig. 4. Blast Regulator Drive

it in terms of a 100-ton-per-day plant or on the basis of the industry's 10,000,000 tons per year.

Ultimate Solution

That gas analysis is an accurate key to the combustion reactions in the cupola, and hence to general operation, is now generally conceded and installations of standard instruments for indicating and recording CO_2 are in use at several foundries.

An example of such use is at the Council Bluffs plant of the Griffin Wheel Company. In this particular industry close control of chemical composition and temperature is of utmost importance for there is probably no more delicate reaction than that of chilling iron. Importance is increased by the fact that the chilled iron car wheel industry, itself, represents a production of approximately 600,000 tons per year. Too much silicon and the reaction rate of the graphitization of the combined carbon is increased so that a wheel deficient in wearing surface is produced whereas too little silicon extends the harder carbide down into the plate or interior of the wheel, making it brittle and lowering the factor of safety.

The relative chilling properties of a particular ladle of metal are predicted by casting a chilled test block. From the appearance of the broken test block the cupola operator corrects the following taps by ladle additions of chromium to deepen the chill, or silicon-manganese to lighten the chill.

That the CO_2 indicator is a reliable prognosticator of elemental loss, and hence of chill characteristics, is illustrated by the following figures tabulated from a month's operation at the Griffin Wheel plant. The CO_2 figures represent the daily averages and the treatment column represents the total additions of the elements made during the day.

MONTH OF AUGUST 1938

	Treatment		Av.
Aug.	Cr.	S.M.	CO_2
1	28	18	12.2
3	..	78	...
5	..	23	12.7
8	27	11	12.2
10	9	45	13.5
12	24	..	13.0
15	..	76	13.9
17	.	39	12.4
19	..	92	13.7
22	1	44	13.3
24	..	56	13.7
26	51	5	12.9
29	..	122	14.1
31	14	36	13.0

While no quantitative relationship can be drawn up from such a table the trend may be easily noted—the higher CO_2 means lower chill and so the hardening chromium is added, while with the lower CO_2 the chill is too high and so the graphitizing silicon is added.

The next logical step in the development of an automatic regulator would be a consideration of the various factors affecting combustion and from these choose one that is reliable and adaptable to regulation. Rather than to attempt a detailed theoretical discussion in a paper of this scope, the various considerations will be briefly enumerated.

(1) The coke ratio—usually expressed in pounds of iron melted per pound of coke.

(2) The blast temperature—which with the hot blast cupola preheats the entering air by utilizing the waste heat content of the top gases. The added heat energy of the hot blast provides a valuable adjunct to the heat developed by the burning of the coke and so permits a lower coke ratio.

(3) The amount of air.

Because once installed the hot blast is designed to operate normally at a fixed temperature and because the coke ratio would not be amenable to flexible control, so by a process of elimination the volume or weight of air is arrived at as the logical controllable factor for combustion regulation.

The next stage of development took the form of installing a blast volume recorder in conjuction with the CO_2 recorder so that an explanation of the variations in CO_2 could be made on a basis of the amount of air entering the cupola.

However, before the correlation of the two recorder charts could be utilized in calibrating of an automatic controller, two problems in connection with the analyzer had to be tackled. First was the development of a suitable filter for the gases; second was the location of the sampling tubes. At this writing, the second problem is still in the stage of development.

The finally arrived set-up is composed of a standard recording controller, with the gases drawn from the cupola by means of a sampling pipe located 90° from the charging door, which position was selected by experiments as giving a representative average of the gases across the entire cross-sectional area of the cupola. The tubes are placed low enough below the charging door to prevent contamination of the gas sample by any free air that might come from the down-draft.

(Continued on page 279)

An Audio-Frequency Spectrometer

By R. K. HELLMAN

Electrical Engineer, Transatlantic Research, Inc., New York City

This paper received the Second Prize in the First Annual Instrumentation Contest

AN ELECTRIC WAVE ANALYZER is described herein, which permits making instantaneous measurements of the amplitudes of any frequency components present in a complex sound or electric wave. All of these components being made visible simultaneously, the spectrum of the wave to be analyzed is shown as is done in optical technique. Though the frequency range of the device is immaterial, its design makes it particularly practical for audio and supersonic frequencies.

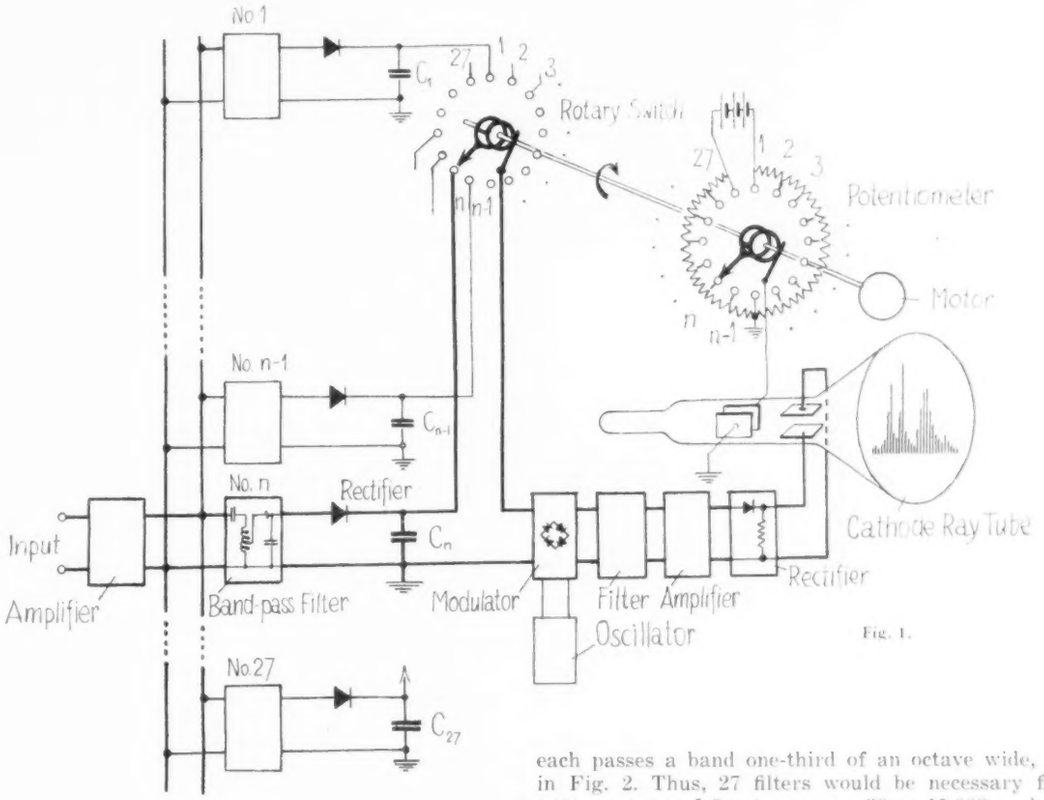


Fig. 1.

The measuring instrument used in the device is a cathode-ray tube of conventional design. No special requirements as to sensitivity, focussing, or brillancy of the spot are to be met. However, good alignment of the deflecting system and a screen of relatively long persistence are desirable. For the sake of simplicity it is assumed in the following that the tube has electrostatic deflection and is of the vacuum type, though these features are not essential for the application to be considered. The screen diameter may be 5 inches. There are at present several well-known methods of analyzing sound or electric waves. The one probably most frequently used employs a type of superheterodyne receiver with narrow i-f. filter. As the oscillator frequency is varied, the magnitude of the output voltage indicates such frequency components as are present at the input. This method has the following drawback, which is also typical of all other older analyzing methods: If the spectrum is to be analyzed accurately, the filter used must be extraordinarily narrow (in the order of a few cycles). With such a filter the building-up time is considerable ($t = \frac{1}{2}\pi f$ seconds, f being the band width), so that it takes an impractically long time to scan the spectrum. It is, therefore, impossible with these methods to analyze short-lasting or fast-changing sounds.

In the device herein described this difficulty is overcome in the following way. Referring to Fig. 1, the input voltage, after amplification, is fed into a system of band-pass filters connected in parallel. These filters are so designed that each passes a band one-third of an octave wide, as shown in Fig. 2. Thus, 27 filters would be necessary for a frequency range of 9 octaves, *e.g.*, 30 to 15,000 cycles. (These filters are inexpensive, as brought out below.) Across the output of each filter is connected a copper oxide rectifier, through which a condenser is charged. If the array consists of 27 channels, the rectified voltage stored in the 27 condensers represents a true picture of the frequency components present in the input.

By means of this invention, these condenser voltages are made visible as vertical lines on the screen of a cathode-ray tube, each condenser, and hence each frequency, being assigned a definite place on the horizontal axis. Thus, a "spectrum" consisting of individual lines is formed on the screen. This is achieved by "scanning" the condensers periodically at such a speed (*e.g.* 20 times a second) that the image on the screen appears stationary as long as the input voltage remains unchanged. One may picture the scanning achieved by means of a rotary switch which has two contact arms and rotates at 1200 r.p.m. One arm connects successively the condenser terminals with the vertical deflecting plates of the c-r. tube (through an amplifier circuit described below); the second arm slides on the contacts of a "potentiometer" resistor which has as many steps as there

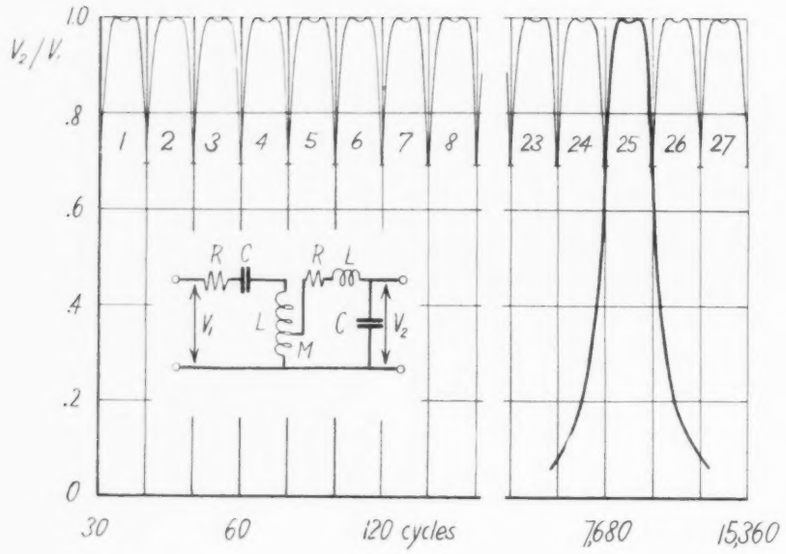


Fig. 2.

Fig. 3.

are condensers and is connected with a d-c. source. This arrangement results in a "frequency axis" appearing on the screen. In order that the amplitudes of the frequency components may appear as *solid* vertical lines, it is advisable to transform the d-c. voltage across the condenser into a.c. by means of modulation. Such a circuit is shown (as a block diagram) in Fig. 1. An oscillator supplies a voltage of a few thousand cycles which will appear at the modulator output proportional in amplitude to the d-c. input. The modulator may be of the well-known bridge type using copper oxide rectifiers, or of any other kind. The "sideband" frequency—which in this case is identical with the oscillator frequency—may be filtered and, after amplification, is rectified by means of a half-wave linear rectifier. The voltage thus obtained is fed to the vertical deflecting plates of the c-r. tube. In this way, the components appear on the screen as vertical lines starting from the frequency axis as zero. An example of the spectrum as it appears on the screen is shown in Fig. 1.

The arrangement permits making a permanent record of the spectrum by means of a small-film camera, by reason of the negligible time lag of the readings. There are no limitations due to the transient time of the filters. The speed of the measurement depends upon two factors:

(1) on the speed of the rotary switch, the time of one revolution being the maximum allowed for each condenser to build up its charge;

(2) on the time constant of the rectifier circuits. When recording fast-changing sounds, this should be smaller than the time required for one revolution. In some cases, however, particularly when brief sounds are to be analyzed, it may be advisable to make the time constant of the rectifiers relatively long. By the sudden sound, a charge will then be set up and kept in those condensers which correspond to the frequencies present, and consequently a spectrum slowly decreasing in amplitude will appear on the screen long after the sound has actually passed. It will therefore be helpful to associate with each of the normal condensers another one of much greater capacity; these condensers may be connected in parallel by means of a multiple switch in such cases as mentioned.

The attenuation curve of the filters is of importance with regard to the performance of the device as well as to the costs. The design shown in Fig. 2 was found most satisfactory in both respects. Each filter consists of two resonant circuits which are coupled magnetically to such an extent that a double-humped curve is produced, which drops 30% at the points of intersection with the adioining curves. In this way the r.m.s. value of the lines indicated is approximately independent of the position of the components relative to the filters. The filter circuits may be designed according to the following formulae:

Resonant frequency	$\omega_o = 1/\sqrt{LC}$
Damping factor	$d = R/\omega_o L$
Coupling factor	$k = \sqrt{M/L}$
Frequency deviation	$y = \omega/\omega_o - \omega_o/\omega$
Filter curve	$V_2/V_1 = \dfrac{k}{(d+jy)^2 + [(\omega/\omega_o)k]^2}$

In actual construction, a switch rotating at 1200 r.p.m. would cause considerable trouble. It therefore is replaced by a cam-operated switch with 2×27 contacts. Such switches were developed originally for other purposes and

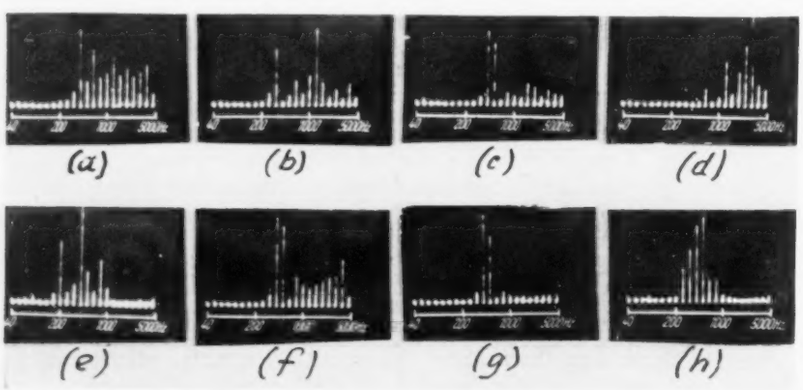


Fig. 4. Experiments on a violin.

(a) G-string, full length, fundamental frequency approx. 200 cycles; (b) D-string, full length, approx. 300 cycles; (c) A-string, full length, 435 cycles; (d) E-string, full length, approx. 650 cycles. (e) G-string, full length, touched at 1/4 length; (f) "a" played on A-string; (g) "a" played on D-string; (h) spectrum produced by knocking on back of violin.

are working satisfactorily under even more difficult conditions.

A model of the device which incorporates all the features mentioned is shown in Fig. 3.

Applications: The device may be helpful in connection with many industrial measurements, particularly in the following fields:

Stationary sound waves: Noise caused by gas engines, electrical machinery, airplanes, etc. When used in connection with a vibration pick-up, mechanical vibrations occurring with such machines may be investigated.

In connection with a test generator which supplies a frequency spectrum of uniform height throughout a given frequency range, the device may be used for measuring attenuations; in this field it might well bring about a revolution in the existing methods. It will further be useful in measuring electrical interference voltages and non-linear distortion.

Transients: A large field is that of testing voices, musical instruments, etc. In this case it is particularly helpful to record the variations of the spectrum by means of a 16-mm. camera. Fig. 4 shows some examples of violin sounds produced in different ways. The decay time of the different harmonics, for instance, can be studied—which is of the greatest importance in connection with the timbre of valuable instruments.

An Automatic CO_2 Compensator

(Cont. from page 276)

Special filters, Fig. 2, were designed to eliminate soot, etc., from clogging the line or instrument.

The gas analysing equipment, Fig. 3, is a standard recording-and-controlling Orsat type, located on the foundry floor where the cupola foreman can readily refer to it. Next to the CO_2 recorder is located the air volume recorder.

A special Mercoid switch added to the CO_2 instrument produces means of changing the control point to any stage of combustion. Corrective-action impulses are sent from the controller to an electric drive, Fig. 4, which operates the pop-off valve on a positive blower and thereby varies the air supply to maintain a constant stage of combustion.

The installation is in effective operation. That consistency of control is possible is illustrated in the following table of results of automatic operation of a 76" hot blast (600°F.) cupola. The weight of bed coke was 4400 lbs. (41" above tuyeres); the after coke was 148 lbs. per ton and the total melt was 183 tons.

EXTRACT FROM SHOP RECORD SEPT. 1ST, 1938

TAP	1	2	6	11	17	23	27
Percent CO_2	10	10.5	15.0	15.0	15.0	15.0	15.0
% Net Silicon	0.47	0.54	0.48	0.54	0.55	0.56	0.56
% Net Manganese	0.51	0.53	0.51	0.58	0.51	0.53	0.51
Total Carbon	3.77	3.56	3.55	3.60	3.55	3.60	3.59
% Sulphur	0.140	0.124	0.121	0.130	0.128	0.116	0.117
* % Gross Silicon	0.58	0.60	0.73	0.73	0.73	0.73	0.73
* % Gr. Manganese	0.70	0.77	0.72	0.72	0.72	0.72	0.72
% Silicon Loss	0.11	0.06	0.25	0.19	0.18	0.17	0.17
% Manganese loss	0.19	0.24	0.21	0.14	0.21	0.19	0.21
Temp. of tap (°F.)	2771	....	2700	2680	2700	2715	2700
Temp. of mold (°F.)	2408	2408	2408	2390	2408	2400	2390

*Estimated from charges

The low CO_2 at the beginning of the melt is due to the extra coke of the bed charge, used to obtain the higher initial tapping temperature to compensate for the cold ladles and apparatus. To maintain proper chilling qualities of the iron when operating with the low CO_2, it is necessary for the gross silicon to be reduced because of the lower oxidation loss experienced during this period.

The results show that the automatic CO_2 compensating control for cupola blast is practical. The big problem now will be to overcome the inertia that opposes every attempt to replace long-established hand-controlled operations by instrumentation. If this paper serves in any way to help overcome this resistance, its preparation will not have been in vain.

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A Hydrogen Sulphide Recorder

By WILTON E. STACKHOUSE

United Gas Improvement Co. Engineering Laboratories, Chester, Pa.

This paper received the Third Prize in the First Annual Instrumentation Contest

A HYDROGEN SULPHIDE recorder is described herein, which is capable of determining traces of this constituent when present in city gas or air. A colorimetric reagent is used and registration of color intensities is accomplished by means of photocells and a potentiometer recorder. The total service time required by the recorder averages about three man-hours per week.

NATURE OF THE PROBLEM

The manufactured gas industry is required by law to remove all but a "trace" of hydrogen sulphide from gas supplied to the consumer. A trace has been defined legally in this case as being 0.1 grain H_2S per 100 ft.^{3} of gas. One grain of H_2S occupies a volume of 0.00157 ft.^{3}, so that one-tenth grain represents 0.000157%, the maximum allowable concentration. Except in rare cases, purification of gas from H_2S is well within this limit. A penalty is imposed for exceeding this value.

The usual method for qualitative estimation of city gas purity from H_2S is the lead acetate paper test, in which the gas to be tested is passed over a strip of filter paper moistened with lead acetate solution. In the approved apparatus, a three-minute exposure of the paper to gas containing 0.1 gr. H_2S per 100 ft.^{3} will produce a "faint" discoloration. Obviously, this test is not suitable for quantitative estimation of H_2S concentration and since the threshold value is the legal maximum, it is of little value as a "control" test.

The approved quantitative method for determination of H_2S concentration consists of reacting H_2S contained in a measured volume of gas with cadmium chloride or acetate solution, forming cadmium sulphide which then is determined iodometrically. With city gas the absorption must be continued for about seventy-two hours before sufficient H_2S has been passed to allow a measureable amount of cadmium sulphide to form. Because of the time element, this test likewise is obviously valueless as a control method.

Therefore the need is for an apparus which will *measure* (and indicate or record) the H_2S concentration in city gas, and which will have negligible lag.

THE HYDROGEN SULPHIDE RECORDER

Because of the inherent disadvantages of these analytical methods, there was proposed and developed a recorder with the following characteristics:

1. The Range may be varied to meet the requirements. A range of 0.0 to 0.5 gr. H_2S per 100 ft.^{3} has been used for purified city gas. The scale is straight-line-uniform for this range, having a least scale division of 0.01 gr.

2. Ultimate Sensitivity. The recorder will respond to changes in concentration of 0.005 gr. H_2S per 100 ft.^{3}.

3. The Reagent is specific for H_2S, is stable, unaffected by light, and all reaction products are soluble. Composition:

2.0% (wt) Ammonium molybdate, $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$
1.0% (wt) Ammonium sulphate, $(NH_4)_2SO_4$
0.01% (vol) Acid, sulphuric, 1.84 s.g., 94% H_2SO_4
Distilled water
(Merck reagent grade molybdate and sulphate.)

4. Color, Effect on Photocell Response. The reagent develops shades of blue-green in presence of H_2S, the intensity being proportional to H_2S concentration. The Photronic cells used are most sensitive in this spectral region—whence the high sensitivity of the apparatus.

5. Speed of Response. The recorder has been designed to respond to changes of H_2S concentration within twenty minutes. The time necessary to reach equilibrium with the new concentration will depend upon the magnitude of the change. Speed of response is controlled by the solution rate and the volume of the absorber and liquid system following the absorber.

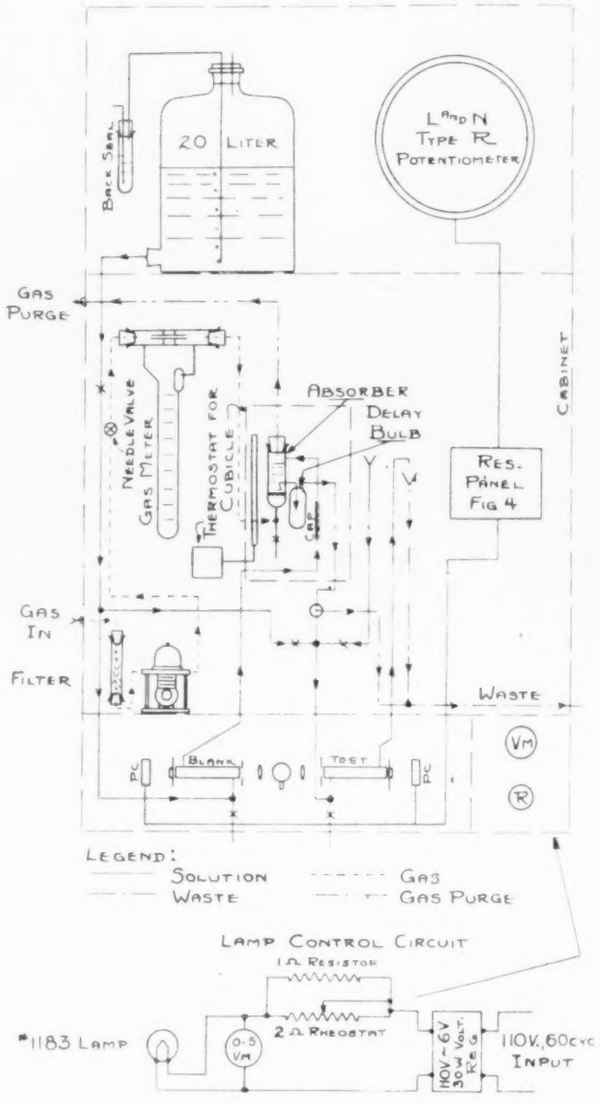


Fig. 1. Flow diagram of hydrogen sulphide recorder.

6. Calibration is by use of color standards made by adding known amounts of an H_2S standard solution to definite quantities of the reagent.

7. The H_2S Standard Solution used for preparing color standards is an aqueous solution of sodium sulphide, Na_2S.

8. Color Standards are prepared by adding known amounts of the sodium sulphide solution to the colorimetric reagent contained in volumetric flasks. Full color develops upon standing for one hour at 70°F. The color standards are stable for four hours after full color development.

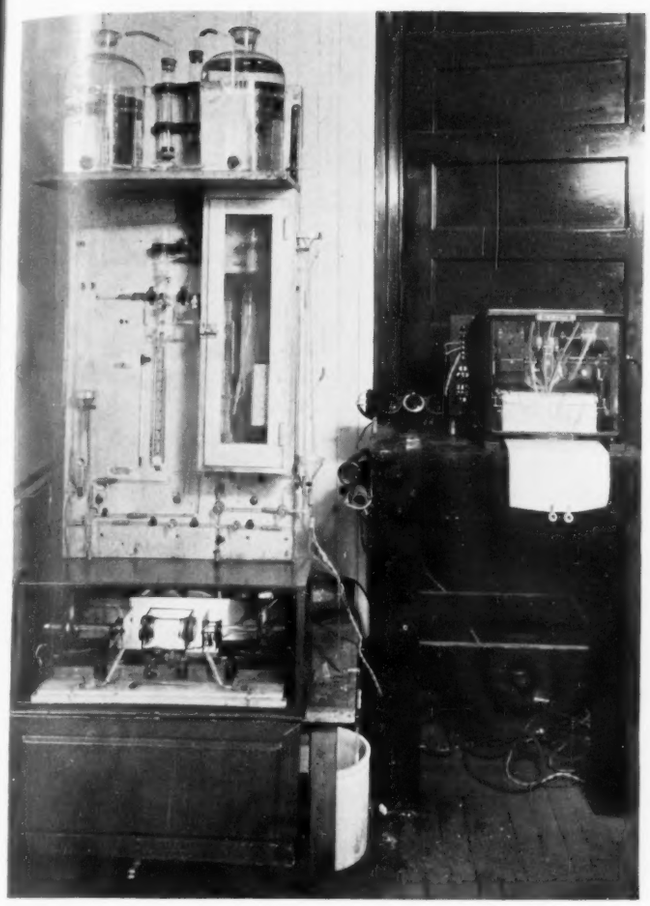


Fig. 2. Experimental hydrogen sulphide recorder.

In normal operation of the recorder the color development is accelerated by heat in order to increase the speed of response.

APPARATUS ASSEMBLY

The form of the recorder is indicated by the flow diagram, Fig. 1. The experimental assembly is shown in Fig. 2: the chemical panel at the left provides assembly of (1) reagent reservoir, (2) gas measuring and absorption system, (3) reagent handling system, (4) constant-temperature cubicle for housing reagent control capillary, absorber, and aging bulb, (5) photocell-optical color comparison system.

The recorder has been designed to operate continuously for a week, at the end of which time the reagent reservoir is refilled and the zero balance of the photocells checked.

The photocell-optical system, Fig. 3, requires the use of a low-voltage, high-intensity lamp such as a G.E. Co. Mazda 1183, 50 c-p, 6v. The lamps are aged prior to installation in the recorder in order to stabilize their light output characteristics. The aging, 96 hours operation at 4.0 volts, has been found to be the optimum. The lamp is operated on the output of a saturated core type of voltage regulator such as the Ward-Leonard or Acme-Delta.

The Photronic cells used are Weston Model 594, equipped with disks D-69902. The recorder requires two cells, the blank or standard and the test cell. Both cells have similar output characteristics and are interchangeable. The output of the photocells feeds into the resistance network panel (immediately to the left of the potentiometer recorder in Fig. 2). The potentiometer recorder measures the potential drop across a fixed resistance contained in the resistance network shown schematically in Fig. 4.

The color comparison tubes are Pyrex cylinders having windows fused to the tube body. The windows are optical grade Pyrex, causing no distortion of the light passing through the tubes.

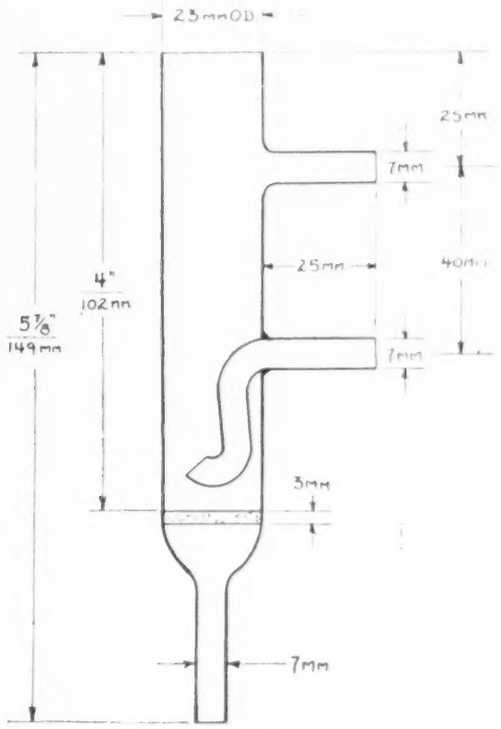


Fig. 5. Details of absorber.

The absorber, Fig. 5, is a modified Allihn filter tube having a Jena sintered glass disk.

The temperature of the cubic for housing the reagent control capillary, gas absorber, and reagent aging bulb is thermostatically controlled. A Minneapolis-Honeywell Type T-415 bulb controller was used to control a 100-ohm, 110-volt resistor as a heater, maintaining a temperature of 110°F.

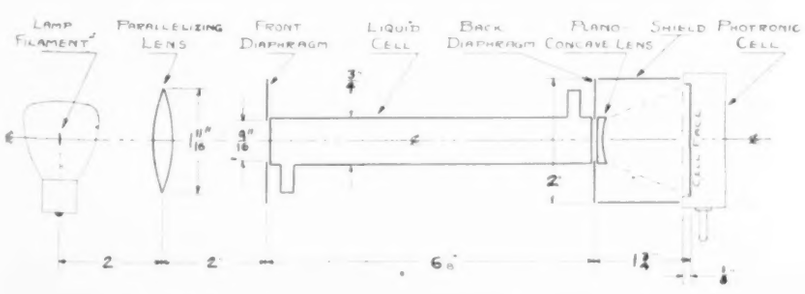


Fig. 3. Optical train (half) for system having full face illumination of Photronic cells.

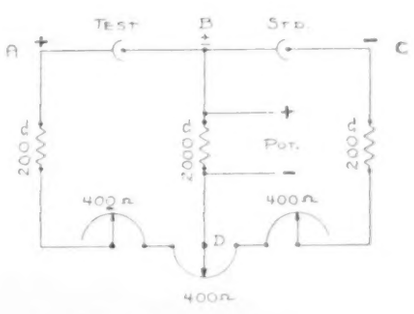


Fig. 4. Photocell resistance circuit.

Fig. 6 illustrates the type of record obtained. The disturbance was not detected by the routine analytical methods used at the plant where the recorder was in operation. Without the warning provided by the recorder, the H_2S concentration would have exceeded the legal limit in this instance.

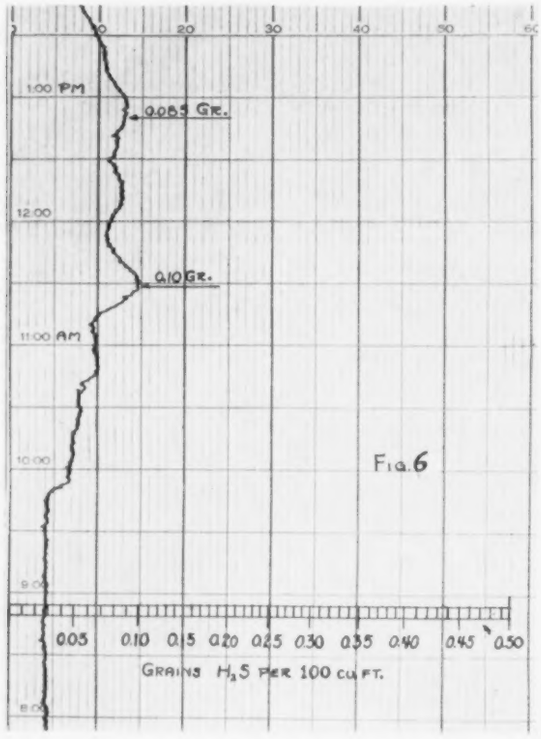


Fig. 6. Portion of actual gas main record.

CALIBRATION CONSTANTS

The H_2S standard solution used for preparation of color standards has an H_2S equivalent of 0.002 gr. per ml. of solution.

The reagent rate used in the recorder was 100 ml./hr.; the gas rate 0.2 ft.^{3}/hr.

By definition, a 1-ml. standard contains 1.0 ml. of H_2S standard for a total of 100.0 ml. of reagent. Therefore, a 1-ml. standard represents a definite H_2S concentration according to the following expression:

$$\frac{\text{(1-ml. std) } 0.002 \text{ gr./100 ml.} \times \text{(sol) } 100 \text{ ml./hr.}}{\text{(gas) } 0.2 \text{ ft}^3\text{/hr.}} = 0.01 \text{ gr./ft.}^3 \text{ or } 1.0 \text{ gr./100 ft.}^3$$

Having established the equivalent in grains per 100 cubic feet of the 1.0 ml. standard, the recorder photocell system is calibrated with a series of color standards covering the desired range.

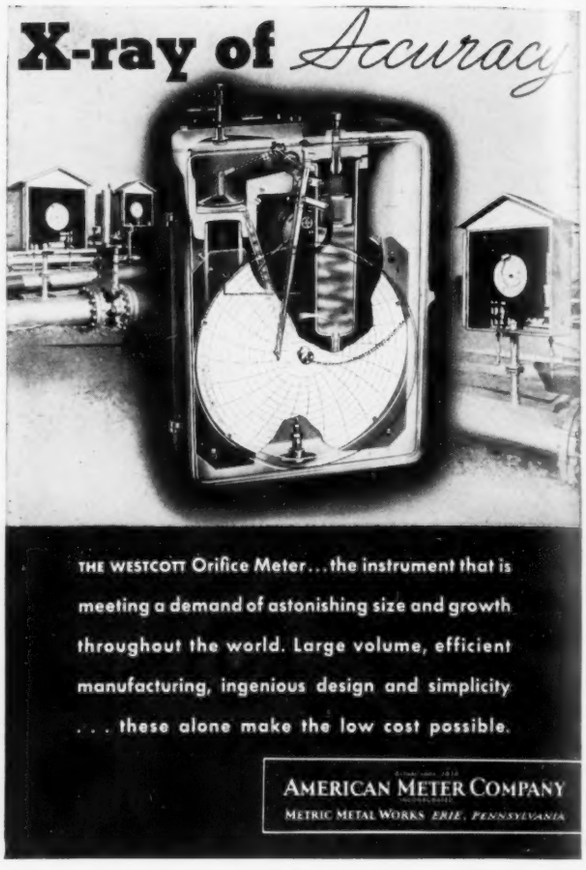
ACCURACY OF THE RECORDER

Following calibration of the recorder with color standards, the accuracy of registration was determined when testing known concentrations. A dynamic method was used for producing known H_2S concentrations in the test gas. The overall precision of the method was $\pm$ 3.0%. The recorder was checked by the approved analytical method, which was found to be less accurate than the recorder as shown by the following results. Comparisons were made over the range 0.2 to 0.6 gr. per 100 ft.^{3}.

Results: H_2S Recorder/H_2S Feed = $1.00 \pm 3\%$
= 0.999 ave. of six

Analytical /H_2S Feed = $1.00 \pm 13\%$
= 0.965 ave. of six

Therefore, from the above data it is evident that the precision of the recorder is within the limits of accuracy of the H_2S feed system and that the average of a number of observations establishes the accuracy as $\pm$ 1% or better.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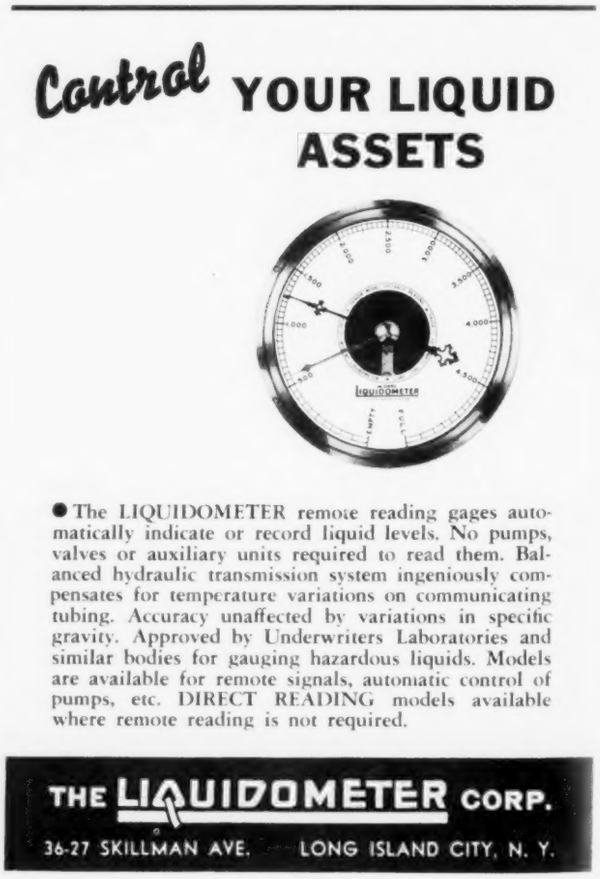
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